

**COMMITTEE ON SCIENCE, SPACE, AND TECHNOLOGY  
U.S. HOUSE OF REPRESENTATIVES**

**HEARING CHARTER**

***“The Legacy of Apollo”***

Tuesday, July 16, 2019  
10:00 AM  
2318 Rayburn House Office Building

**PURPOSE**

The purpose of the hearing is to commemorate the 50<sup>th</sup> anniversary of the Apollo 11 Moon landing.

**WITNESSES**

- **Mr. Charles Fishman**, author of *One Giant Leap: The Impossible Mission That Flew Us to the Moon*<sup>1</sup>
- **Dr. David W. Miller**, Vice President and Chief Technology Officer, The Aerospace Corporation
- **Dr. Peter Jakab**, Chief Curator, Smithsonian Air and Space Museum

**OVERARCHING QUESTIONS**

- *What events and factors led to the decision to pursue the Moon landing and the Apollo program?*
- *What is the legacy of Apollo?*
- *What scientific and technological advancements did the Apollo program enable?*

**BACKGROUND**

On October 4, 1957, the Soviet Union launched Sputnik 1, humanity’s first artificial satellite. The Soviets followed Sputnik 1 by launching the first animal, a dog named Laika, into space on board Sputnik 2. The United States launched its first satellite, Explorer I, on January 31, 1958, which contained scientific instrumentation and led to the discovery of the Van Allen radiation belts. The “Space Race” had begun. Later in 1958, Congress passed, and President Eisenhower signed, the National Aeronautics and Space Act, establishing the National Aeronautics and Space Administration (NASA) from the National Advisory Committee for Aeronautics.<sup>2</sup>

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<sup>1</sup> Charles Fishman, *One Giant Leap: The Impossible Mission That Flew Us to the Moon*, Simon and Schuster, 2019.

<sup>2</sup> Pub. L. No. 85-568, “National Aeronautics and Space Act of 1958,” July 29, 1958.

In 1959, the Soviet Union sent the first ever spacecraft to the Moon, Luna 2. This was followed by several successes in human spaceflight, most notably launching the first human to space and into orbit, Yuri Gagarin, on April 12, 1961. Less than a month later, the U.S. launched Alan Shepard into space on a suborbital trajectory as part of Project Mercury. In 1962, John Glenn became the first American to orbit Earth. The Soviet Union also launched the first woman into space, Valentina Tereshkova, on June 16, 1963.

Fearful that that Soviet Union would lead in space, President John F. Kennedy proposed in a speech to Congress on May 25, 1961, that the U.S. *“should commit itself to achieving the goal, before this decade is out, of landing a man on the Moon and returning him safely to the Earth.”*<sup>3</sup> President Kennedy followed this with a speech in September of 1962 at Rice University in Texas, stating:<sup>4</sup>

*“There is no strife, no prejudice, no national conflict in outer space as yet. Its hazards are hostile to us all. Its conquest deserves the best of all mankind, and its opportunity for peaceful cooperation may never come again. But why, some say, the Moon? Why choose this as our goal? And they may well ask, why climb the highest mountain? Why, 35 years ago, fly the Atlantic? Why does Rice play Texas?”*

*We choose to go to the Moon! We choose to go to the Moon... We choose to go to the Moon in this decade and do the other things, not because they are easy, but because they are hard; because that goal will serve to organize and measure the best of our energies and skills, because that challenge is one that we are willing to accept, one we are unwilling to postpone, and one we intend to win, and the others, too.”*

Project Gemini succeeded the Project Mercury program. Gemini had four main goals: *“to test an astronaut's ability to fly long-duration missions (up to two weeks in space); to understand how spacecraft could rendezvous and dock in orbit around the Earth and the moon; to perfect re-entry and landing methods; and to further understand the effects of longer space flights on astronauts.”*<sup>5</sup> Ten crewed missions in all were flown as part of Project Gemini, allowing the U.S. to surpass the Soviet Union in the Space Race. President Kennedy's challenge would be met in the next phase, Project Apollo.

### Project Apollo

The Apollo program followed the successful completion of Project Gemini with a tragic failure. A fire during an Apollo 1 ground test resulted in the deaths of astronauts Virgil “Gus” Grissom, Edward White, and Roger Chaffee. A nearly two-year hiatus in crewed American spaceflights followed. Apollo 4, an uncrewed flight, successfully demonstrated the power of the Saturn V

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<sup>3</sup> President John F. Kennedy, “Special Message to Congress on Urgent National Needs”, President John F. Kennedy Presidential Library and Museum, May 25, 1961.

<sup>4</sup> President John f. Kennedy, “Text of President John Kennedy's Rice Stadium Moon Speech”, <https://er.jsc.nasa.gov/seh/ricetalk.htm>, accessed July 15, 2019.

<sup>5</sup> NASA, “Gemini”, [https://www.nasa.gov/mission\\_pages/gemini/index.html](https://www.nasa.gov/mission_pages/gemini/index.html), accessed July 12, 2019.

rocket. Apollo 7 returned astronauts to space. Apollo 8 sent the first crewed spacecraft to the Moon, where it orbited ten times. Apollo 9 tested the lunar lander module in Earth orbit, including rendezvous and docking. Apollo 10 was a test run for the first Moon landing. The lunar module got as close as 50,000 feet to the lunar surface and performed rendezvous and docking in lunar orbit.

On July 16, 1969 at 9:32 a.m. EDT, Apollo 11 was launched from Kennedy Space Center in Florida with astronauts Neil Armstrong as commander, Edwin “Buzz” Aldrin as lunar module pilot, and Michael Collins as command module pilot. Three days later, Apollo 11 reached lunar orbit. After surveying prospective landing spots, the lunar module containing Armstrong and Aldrin separated from the command module, while Collins stayed behind in the command module. The lunar module, piloted by Armstrong, landed at 4:17 p.m. EDT on July 20. Armstrong indicated their success by telling mission control, “*Houston, Tranquility Base here. The Eagle has landed.*”

At 10:56:15 p.m. EDT, July 20, 1969, Neil Armstrong became the first human to set foot on the Moon, saying, “*That’s one small step for [a] man, one giant leap for mankind.*”<sup>6</sup> Buzz Aldrin soon joined him on the surface. Over the course of the next two hours, Armstrong and Aldrin collected 22 kilograms of lunar rocks and dust,<sup>7</sup> deployed multiple scientific experiments, including a seismometer and a retroreflector, and planted the American flag. The two astronauts spent nearly 22 hours on the surface of the Moon before launching back into lunar orbit to dock with the command module, piloted by Collins. At 12:50 p.m. EDT on July 24, they splashed down safely in the Pacific Ocean.

NASA launched six more Apollo missions; five successfully reaching different locations on the Moon’s surface. Apollo 13 experienced a major failure when an oxygen tank exploded, but the crew, in collaboration with mission control and ground crew, managed to work around multiple constraints to bring the Apollo 13 crew safely back to Earth. The astronauts on each successive, successful Apollo mission carried out longer Moon walks and performed more scientific experiments than the previous ones. Apollo 15, 16, and 17 astronauts drove the Lunar Roving Vehicle on the surface to explore farther and collect a more diverse set of lunar rocks and dusts. In total, Apollo astronauts brought back 382 kilograms of lunar material to be used mostly for scientific purposes, but also as goodwill gifts to states and foreign heads of state.

In 1973, NASA reported the cost of the Apollo program to be \$25.4 billion, which has been estimated to be around \$260 billion in FY 2019 dollars, according to a June 17, 2019, article from *The Space Review*.<sup>8</sup> That article also reanalyzes the costs of the Apollo program and estimates the total lunar effort to have actually been \$288 billion in FY 2019 dollars. More than 400,000 people worked on Apollo either directly or through contracts.<sup>9</sup>

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<sup>6</sup> NASA, “Apollo 11 Timeline”, [https://history.nasa.gov/SP-4029/Apollo\\_11i\\_Timeline.htm](https://history.nasa.gov/SP-4029/Apollo_11i_Timeline.htm), accessed July 12, 2019.

<sup>7</sup> Universities Space Research Association, “Apollo 11 Mission”, [https://www.lpi.usra.edu/lunar/missions/apollo/apollo\\_11/samples/](https://www.lpi.usra.edu/lunar/missions/apollo/apollo_11/samples/), accessed July 12, 2019.

<sup>8</sup> Casey Dreier, “A new accounting for Apollo: how much did it really cost?”, *The Space Review*, June 17, 2019.

<sup>9</sup> NASA, “NASA Langley Research Center’s Contributions to the Apollo Program”, <https://www.nasa.gov/centers/langley/news/factsheets/Apollo.html>, accessed July 12, 2019.

## Geopolitical Impacts

The successful Apollo 11 Moon landing and the subsequent Apollo Moon landings are largely viewed as the culmination of the Space Race.<sup>10</sup> It symbolized American power and prestige. A U.S. survey of foreign public opinion found that the rest of the world viewed the Apollo 11 Moon landing as “an achievement of all mankind,” that it “should serve to bring mankind closer together,” and that it led to a “high degree of personal identification with the United States” due to the very open, public nature of the event.<sup>11</sup> Indeed, messages from 73 world leaders were left on the Moon in a silicon disc by the Apollo 11 astronauts.<sup>12</sup> After landing, the three astronauts went on a 24-nation world tour,<sup>13</sup> where they were greeted by hundreds of thousands to even millions of people at each event.<sup>14</sup> President Nixon used the success of Apollo 11 to land a meeting with Romanian President Ceaușescu, who passed along messages to China and Vietnam. This later led to normalization of relations between the U.S. and China and North Vietnam.<sup>11</sup>

Soon after the Apollo 11 Moon landing, the Soviet program to land people on the Moon ended. In 1975, the last Apollo mission, the Apollo-Soyuz Test Project, entailed a joint U.S.-Soviet mission in which an Apollo command/service module docked with a Soviet Soyuz capsule, formally ending the Space Race. This began the first of many collaborative efforts between the United States and the Soviet Union (and now Russia) in space exploration.<sup>15</sup>

## Research and Development Impacts

The Apollo Moon landing, watched on television by hundreds of millions of people, was recorded using the lens of a compact camera specifically built for space, and “Moon Boot” material greatly improved both shock absorption and stability in athletic footwear.<sup>16</sup> These are just two of the many new technologies that had to be developed specifically for the Apollo missions. Many of these technologies were spun off into commercial projects. The Space Foundation’s Space Technology Hall of Fame has inducted 11 technologies from Apollo, including cordless tools, liquid-cooled garments, an improved fire fighter breathing system, fire-resistant aircraft seats, and anti-shock trousers, among others.<sup>17</sup>

One of the most significant breakthroughs from the Apollo mission was the use of newly invented integrated circuit chips. Today, computer chips are foundational to our technology-

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<sup>10</sup> W. David Compton, *Where No Man Has Gone Before: A History of Apollo Lunar Exploration Missions*, accessed at <https://history.nasa.gov/SP-4214/ch1-1.html> on July 12, 2019.

<sup>11</sup> Teasel Muir-Harmony, “American Foreign Policy and the Space Race”, <https://doi.org/10.1093/acrefore/9780199329175.013.27>, accessed July 12, 2019.

<sup>12</sup> NASA, “Apollo 11 Goodwill Messages”, [https://history.nasa.gov/ap11-35ann/goodwill/Apollo\\_11\\_material.pdf](https://history.nasa.gov/ap11-35ann/goodwill/Apollo_11_material.pdf), accessed July 12, 2019.

<sup>13</sup> Smithsonian Air and Space Museum, “Apollo World Tour”, <https://airandspace.si.edu/multimedia-gallery/7332hjpg>, accessed July 12, 2019.

<sup>14</sup> Chabeli Herrera, “How Apollo 11 dazzled the world: Moon maps in the Netherlands and American flags in Japan”, *Orlando Sentinel*, June 23, 2019

<sup>15</sup> Richard J. Samuels, *Encyclopedia of United States National Security*, SAGE Publications, Dec 21, 2005.

<sup>16</sup> NASA, “Benefits from Apollo: Giant Leaps in Technology”, accessed at [https://www.nasa.gov/sites/default/files/80660main\\_ApolloFS.pdf](https://www.nasa.gov/sites/default/files/80660main_ApolloFS.pdf), July 2004.

<sup>17</sup> Space Foundation, “Space Technology Hall of Fame”, <https://www.spacefoundation.org/what-we-do/space-technology-hall-fame>, accessed July 12, 2019.

driven society. In the early 1960s, however, the chip was had not yet been tested, and its dependability was largely unknown. Despite some initial concerns, NASA used chips supplied by MIT in the Command/Service and Lunar Modules.<sup>18</sup> NASA's willingness to deploy a new, innovative technology on such a high-profile, dangerous mission helped launch the computer age.<sup>19</sup>

The Apollo program enabled groundbreaking science, the legacy of which has a lasting impact today. One of the greatest scientific legacies of Apollo has resulted from the analysis of some of the 382 kilograms of lunar rock and soil samples returned to Earth. Unopened samples from Apollo are still being allocated to researchers, which has led to breakthroughs about the history of the Moon and the Solar System.<sup>20</sup> The Apollo missions also enabled various geophysical investigations using seismology, surface gravimetry and magnetometry, heat-flow measurements and the deployment of laser reflectors used to measure the distance to and on the moon.<sup>21</sup> Results from Apollo have informed scientists' understanding of water on the Moon,<sup>22</sup> the origin of the Moon,<sup>23</sup> and the origin of our own planet Earth.<sup>24</sup>

### Cultural Impacts

The Apollo 11 mission was a global event. An estimated one million spectators watched the launch of Apollo 11 in person, including President Johnson, Vice President Agnew, 19 governors, 200 Congressmen, and 60 ambassadors, and another 25 million Americans watched on live TV, which was also broadcast to 33 other countries around the world on six continents.<sup>25</sup> NASA estimates that 650 million people watched Armstrong step onto the lunar surface, about 18 percent of the world population at the time, while the Voice of America broadcast it over radio in 36 languages to another estimated 750 million people.<sup>26</sup>

Historians credit the Apollo program with helping inspire a new wave of environmentalism,<sup>27</sup> particularly by the Apollo 8 *Earthrise* photo and the Apollo 17 *The Blue Marble* photo. The first Earth Day took place less than a year after the first Moon landing in 1970. That same year,

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<sup>18</sup> Paul Ceruzzi, "Apollo Guidance Computer and the First Silicon Chips", Smithsonian National Air and Space Museum, October 14, 2015.

<sup>19</sup> Sharon Gaudin, "NASA's Apollo technology has changed history", *Computer World*, July 20, 2009.

<sup>20</sup> NASA, "NASA Selects Teams to Study Untouched Moon Samples", <https://www.nasa.gov/feature/nasa-selects-teams-to-study-untouched-moon-samples>, March 11, 2019.

<sup>21</sup> Ian A. Crawford, *Astronomy & Geophysics*, Volume 53, Issue 6, pp. 6.24-6.28, December 2012.

<sup>22</sup> Freeman, J.W., Jr., H.K. Hills., R.A. Lindeman, and R.R. Vondrak, "Observations of Water Vapor at the Lunar Surface", *The Moon*, 8, 115–128, 1973

<sup>23</sup> U. Weichert, et al. "Oxygen Isotopes and the Moon-Forming Giant Impact", *Science*, 294, 345, 2001.

<sup>24</sup> Ron Cowen, "Common source for Earth and Moon water", *Nature*, May 9, 2013.

<sup>25</sup> Charles D. Benson William Barnaby Faherty, *Moonport: A History of Apollo Launch Facilities and Operations*, The NASA History Series, 1978.

<sup>26</sup> NASA, "Apollo 11 Mission Overview", [https://www.nasa.gov/mission\\_pages/apollo/missions/apollo11.html](https://www.nasa.gov/mission_pages/apollo/missions/apollo11.html), accessed July 12, 2019.

<sup>27</sup> Andrew Chaikin, "Live from the Moon: The Societal Impact of Apollo", *Societal Impact of Spaceflight*, accessed at <https://history.nasa.gov/sp4801-chapter4.pdf> on July 12, 2019.

President Nixon created the Environmental Protection Agency, which is widely considered an indirect result of Apollo.<sup>28</sup>

NASA's space program inspired a new generation to go into science, technology, engineering, and math (STEM) fields. During the 1960s, the number of PhDs graduating from American universities tripled, with a particularly strong increase in the field of physics.<sup>29</sup>

At the time, however, the Apollo program did not enjoy universal support from the American people. A 2003 study by former NASA Chief Historian Roger Launius found that, throughout the 1960s, polls showed that "a majority of Americans did not believe Apollo was worth the cost, with the one exception to this a poll taken at the time of the Apollo 11 lunar landing in July 1969."<sup>30</sup> This view was echoed by a number of Members of Congress and other opinion leaders, given the other national demands on scarce resources, including the Vietnam War and other Great Society initiatives.

There was also criticism from civil rights activists who saw the funding required for the space program as money that could have been better spent improving the lives of minorities. A *New York Times* article from July 27, 1969, just days after the first Moon landing, was entitled "Blacks and Apollo: Most Could Have Cared Less."<sup>31</sup> Additionally, few women and people of color were part of the program, although there were trailblazers like Margaret Hamilton, JoAnn Morgan, and Poppy Northcutt. The role of Black women in particular in Apollo remained largely hidden for decades, although their critical contributions are now beginning to become more widely known, such as the "Hidden Figures" (Katherine Johnson, Dorothy Vaughan, and Mary Jackson).<sup>32</sup>

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<sup>28</sup> Moira McGuinness, "Science Wednesday: Earthrise – The Picture That Inspired the Environmental Movement", <https://blog.epa.gov/2009/07/01/science-wednesday-earthrise/>, July 1, 2019.

<sup>29</sup> Christopher Riley, "Apollo 40 years on: how the moon missions changed the world for ever", *The Guardian*, December 15, 2012.

<sup>30</sup> Roger D. Launius, "Public opinion polls and perceptions of US human spaceflight", *Space Policy*, 19, pp 163-175, 2003.

<sup>31</sup> Thomas A. Johnson, "Blacks and Apollo: Most Could Have Cared Less", *New York Times*, July 27, 1969.

<sup>32</sup> Margot Lee Shetterly, *Hidden Figures*, William Morrow and Company, 2016.